Department of Plastic Surgery

POSTOPERATIVE SOFT TISSUE DEFECTS IN THE ANKLE AREA

THE ETIOLOGY AND METHODS OF RECONSTRUCTION

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ACADEMIC DISSERTATION

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I don't want to achieve immortality through my work...
I want to achieve it through not dying.

Woody Allen

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following articles, referred to in the text by their corresponding Roman numerals.

I A.Koski, E.Tukiainen, S.Suominen, S.Asko-Seljavaara: Reconstruction of iatrogenic skin defects of the Achilles tendon region: an analysis of 25 consecutive patients. Eur J Plast Surg (2003) 26: 298–303.

II A.Koski, H.Kuokkanen, E.Tukiainen: Postoperative wound complications after internal fixation of closed calcaneal fractures: A retrospective analysis of 126 consecutive patients with 148 fractures. Scand J Surg (2005) 94:243–245.

III E.A.Koski, H.O.M.Kuokkanen, S.K.Koskinen, E.J.Tukiainen: Reconstruction of soft tissue after complicated calcaneal fractures. Scand J Plast Reconstr Surg Hand Surg (2004) 38: 284–287.

IV E.Tukiainen, A.Koski: Microvascular soft tissue reconstructions after complicated talocrural arthroplasty. Eur J Plast Surg (2004) 27: 298–300.

V E.A.Koski, H.O.M.Kuokkanen, E.J.Tukiainen: Distally-based peroneus brevis muscle flap: A successful way of reconstructing soft tissue defects of the ankle. Scand J Plast Reconstr Surg Hand Surg (2005) 39: 299–301.

ABBREVIATIONS

ABI	ankle brachial pressure index
ALT	anterolateral thigh flap
LD	latissimus dorsi
NPWT	negative pressure wound treatment
PB	peroneus brevis
RF	radial forearm
TC	talocrural
TCA	talocrural arthroplasty

ABSTRACT

The risk is obvious for soft tissue complications after operative treatment of the Achilles tendon, calcaneal bone or after ankle arthroplasty. Such complications after malleolar fractures are, however, seldom seen. The reason behind these complications is that the soft tissue in this region is tight and does not allow much tension to the wound area after surgery. Furthermore the area of operation may be damaged by swelling after the injury, or can be affected by peripheral vascular disease. While complications in this area are unavoidable, they can be diminished.

This study attempts to highlight the possible predisposing factors leading to complications in these operations and on the other hand, to determine the solutions to solve soft tissue problems in this region.

The study consists of five papers. The first article is a reprint on the soft tissue reconstruction of 25 patients after their complicated Achilles tendon surgeries were analysed. The second study reviews a series of 126 patients after having undergone an operative treatment of calcaneal bone fractures and analyses the complications and possible reasons behind them. The third part analyses a series of corrections of 35 soft tissue complications after calcaneal fracture operations. The fourth part reviews a series of 7 patients who had undergone complicated ankle arthroplasties. The last article presents a series of post operative lateral defects of the ankle treated with a less frequently used distally based peroneus brevis muscle flap and analyses the results.

What can be conducted from these studies is that in general, the results after the correction of even severe soft tissue complications in the ankle region are good. For the small defects around the Achilles tendon, the local flaps are useful, but the larger defects are best treated with a free flap. We found that a long delay from trauma to surgery and a long operating time were predisposing factors that lead to soft tissue complications after operatively treated calcaneal bone fractures. The more severe the injury, the greater the risk for wound complication. Surprisingly, the long-term results after infected calcaneal osteosyntheses were acceptable and the calcaneal bone seems to tolerate chronic infections very well if the soft tissue is reconstructed successfully. Behind the complicated ankle arthroplasties, unexpectedly high number of cases experiencing arteriosclerosis of the lower extremity was found. These complications lead to ankle fusion but can be solved with a free flap if the vascularity is intact or can be reconstructed. For this reason a vascular examination of the lower extremity arteries of the patients going to ankle arthroplasty is strongly recommended. Moreover postoperative lateral malleolar wound

infections which typically create lateral ankle defects can successfully be treated with a peroneus brevis muscle flap covered with a free skin graft.

1. INTRODUCTION

Postoperative soft tissue breakdown and infection in the ankle area are well-recognized problems in orthopaedic and trauma surgery. The incidence of these problems varies according to the prior operation (Paavola et al 2000, Folk et al 1999, Nagashima et al 2004). The reconstruction of soft tissue in this area is very challenging, even without the swelling of the tissues, due to the limited amount of local tissue available (Tu et al 1999, Vlastou 1995). For reconstruction, the likeness of the soft tissue is especially important in the plantar skin as it is needed and important for durance when absorbing the body weight during walking and running (El-Shazly et al 2008). However, the damage caused by the initial trauma or the prior operation often limit the use of local flaps and as a result, fewer local flaps can be used in the ankle area (Lee et al 2000, Touam et al 2001).

The choice of the reconstructive method can only be made after the infected wound has been cleaned of dead and infected tissue. For small and narrow defects the wound can sometimes be treated with a secondary closure. The reconstruction can be made easier by using negative pressure wound therapy that can start up the granulation process (Schlatter and Hirshorn 2008).

The choice of a local flap is determined by the defect size, shape and the underlying structures. In small defects, local skin and muscles can be transpositioned, whereas in the larger defects substantially large propeller flaps can be used (Bach et al 2007, Chattar-Cora and Pedersen 2006, Pignatti et al 2008, Schaverien and Saint-Cyr 2008). However, the microvascular flap is still the best option in large defects and cavities (Nasir and Aydim 2008, Yazar et al 2006),

This study was conducted to assess the predisposing factors for postoperative soft tissue defects and to evaluate the different methods for the soft tissue reconstruction of the soft tissue in the ankle area.

2. REVIEW OF THE LITERATURE

2.1 INCIDENCE AND CHARACTERISTICS OF WOUND COMPLICATIONS IN THE ACHILLES TENDON REGION

Operations on the Achilles tendon are usually performed because of Achilles tendon ruptures or due to tendinitis. Especially rupture repair surgery is a common procedure in Finland (Leppilahti et al 1996). For instance surgery is needed in 25% of the athletes with Achilles tendon overuse injuries (Kvist 1994).

The rupture repair operation is more often performed openly than percutaneously. This open repair consists of simple end-to-end suturing of the ruptured tendon with possible reinforcement (Lindholm 1959, Nyyssönen et al 2003). In order to minimise the soft tissue complications, the percutaneous technique was developed (Ma et al 1977). However, the percutaneous repair has a similar re-rupture rate than the conservative treatment (Maes et al 2006). Therefore this type of repair has not become the method of choice in the surgery for the Achilles tendon rupture repair, even though it may reduce the rate of postoperative infections (Khan et al 2004).

In the chronic tendinitis of the Achilles tendon, the operative procedure consists of releasing the adhesive tissue around the tendon. This may even improve the nutrition of the tendon (Maffulli and Kader 2002).

Nonetheless, wound complication can be seen in 2.4 –20% of the cases (Maagaard Mortensson and Pedersen1990, Paavola et al 2000, Wills et al 1986). A recent study by Saxena found that the number of post operative wound infections may be as low as 3% when monofilament absorbable sutures were used subcutaneously (Saxena et al 2008).

2.2 INCIDENCE AND CHARACTERISTICS OF WOUND COMPLICATIONS IN CALCANEAL FRACTURES

Calcaneal fractures are most often caused by a fall (Raymakers et al 1998) and the dislocated calcaneal fractures are usually treated operatively. As the calcaneal fracture usually causes oedema to the ankle region, it is recommended that the operation to be performed either immediately or be delayed until the oedema decreases and the skin wrinkles (Al-Mudhaffar et al 2000, Thermann et al 1998, Zwipp et al 1993).

The incidence of postoperative wound infection in Calcaneal fractures varies in different studies between 2.7–25% (Bèzes 1993 et al,Chan et al 1995, Folk 1999 et al). Commonly one-half of open fractures are superficial and heel without reconstructive operation (Heier et al 2003).

2.3 INCIDENCE AND CHARACTERISTICS OF WOUND COMPLICATIONS IN ANKLE ARTHROPLASTY

The talocrural arthroplasty (TCA) is performed for those patients with ankle joint arthritis (either posttraumatic or osteoarthritic) or with rheumatoid arthritis. The first generation of ankle prosthesis were cemented and had numerous problems, such as wound healing problems, as well as the loosening and migration of the components,(Bolton-Maggs et al 1985, Unger et al 1988). By contrast, the second generation is noncemented and seems to have less postoperative complications, but complications do exist and the long-term results have yet to be seen (Conti and Wong 2001, Wood et al 2000). The postoperative wound infection rate is for Ankle prosthesis operations is 1.4–6% (Doets et al 2006, Nagashima et al 2004, Takakura et al 2004,Wynn and Wilde 1992).

2.4 GENERAL FACTORS FOR SOFT TISSUE COMPLICATIONS

Previously it has been well-established that factors correlating positively with postoperative wound complications in the lower leg are diabetes, rheumatoid arthritis, cigarette smoking and advanced age (Abidi 1998 et al , Blotter et al 1999, Escalante and Bearmore 1995, Srinivasan and Moran 2001). Cigarette smokers can have six-fold the risk for postoperative infection compared to non-smokers (Sorensen et al 2003). While local corticosteroid injections are quite common when treating chronic tendinitis, there is no proper evidence to support their use in this indication. On one hand, there have been publications based on experimental studies reporting necrosis in the calcaneal tendon of rabbits at the site of the injection (Balasubramaniam and Prathap 1972). Local corticosteroid injections may also mask the symptoms of tendon damage (DiStefano and Nixon 1973), which may foresee a rupture. This means that the primary diagnosis can be wrong and that the patient has primarily had a partial rupture of the tendon (Kayser et al 2005).

Atherosclerosis is common in patients suffering from rheumatoid arthritis (Chung et al 2007). This can be due to same pathogenic mechanism or to the use of glucocorticoids (del Rincon et al 2004). Whatever the cause is, these patients have a higher risk for postoperative wound edge necrosis (Syahrizal et al 2001).

It is important to note that soft tissue handling is something that cannot be measured, as it only comes with practice. Both in the Achilles tendon surgery and especially in the calcaneus fracture surgery it is necessary to handle soft tissue meticulously (Saxena et al 2008). In both of these types of surgery, the most important factors in the postoperative healing of the wound are the placement of the incision and the timing of the surgery. The higher incidence of wound complications after these operations as compared to other ankle surgery indicates both the complexity of the soft-tissue envelope and the possibility of secondary tissue trauma due to oedema and an operative intervention (Levin and Nunley 1993).

2.5 SOFT TISSUE RECONSTRUCTION WITH LOCAL FLAPS

The skin envelope is especially tight around the ankle and foot. An injury and operation cause oedema and those factors make the skin closure after surgery demanding (Thordarsson et al 1999). There is also usually very little fat under the skin and even a small soft tissue defect can create a major complication if the underlying bone, tendons, joint or hardware become exposed. This is why a free skin graft is seldom a good choice for soft tissue reconstruction (Hallock 1989).

Under the calcaneal bone, in the weight-bearing area, there are special requirements for the soft tissue. The soft tissue has to have the durability needed and to absorb the body weight when walking (Rainer et al 1999, Rautio 1990).

Prior to the invention of microsurgery and free flaps local flaps, were used as a primary method of reconstruction in lower leg soft tissue reconstruction. Lately there has been a renaissance in the use of the local pediculed flaps in the lower leg soft tissue reconstruction (Pinsolle et al 2006). In summary local flaps can be skin flaps, propeller flaps or local muscle flaps (Eren et al 2001, Fix and Vasconez 1991, Jakubietz 2007, Nettelblad and Liedman 1997, Pontén 1981, Sood et al 2001). The local flaps are often easy to raise and as skin flaps, they can have a sensation (Hallock 2000). In addition, the donor site often needs free skin grafting for closure.

2.51 CUTANEUS FLAPS

Cutaneus flaps can be very suitable for the superficial defects in the non-weight-bearing areas. The secondary defect can then be corrected with a free skin graft. The flap can be a rotational type, or especially in the Achilles tendon area, it can be the bipediculed type (Sood et al 2001). For instance a random skin flap has a small area of rotation and its size is also limited to 1:4 (width: length) (Schwabegger et al 1996). A bipediculed flap is lifted so that its both ends are left intact. This flap is moved laterally to cover the defect and the secondary defect is then covered with

a free skin graft. This works well in the long and narrow defects on the posterior and anterior side of the ankle, as well as with the patients having vascular disease (Schwabegger et al 1996).

2.52 NEUROCUTANEOUS FLAPS

Many articles have been published lately on the use of the suralis flap in the reconstruction of the lower leg soft tissue (Ayapppan and Chadha 2002, Costo-Ferreira et al 2001, Fraccalvieri et al 2000). This flap has been previously well described by Masquelet (Masquelet et al 1992), and its long pedicle allows for a wide, tension-free arc of rotation, which has proven to be a reliable tool in the reconstruction of the soft tissue of the lower leg (Chai et al 2008, Fraccalvieri et al 2008).

Masquelet has also published on the use of a neurocutaneous flap in which the vascular pedicle is formed by the vascular axis of the saphenous nerve (Cavadas 1997, Masquelet et al 1992).

2.53 PROPELLER FLAPS

The principles of the propeller flaps were popularized by Hyakusoku (Hyakusoku et al 1991). They have since become a common method for soft tissue reconstruction in almost all the regions of the body. They offer an interesting option for free flaps especially in the lower leg and ankle area. The basic idea is to rotate proximally situated lax soft tissue to the defect area by a 180-degree propeller-like rotation movement (Jakubietz et al 2007). The perforator vessels act as axis of the flap, and these are located with Doppler prior to surgery. During surgery the vessels are freed from the surrounding tissue, thereby making the rotation possible. When these are two veins, one may need to be sacrificed to prevent stasis.

2.54 MUSCLE FLAPS

The local muscle flaps that are predominantly used are the extensor digitorum brevis muscle, the abductor hallucis muscle and the abductor digiti minimi muscles (Mathes et al 1974, Nettelblad and Lidman 1997, Schwabegger et al 2003). The flaps are usually proximally based, but have also been used as distally based flaps (Yoshimura et al 1985, Schwabegger et al 2005). They can be used in defects on the medial and lateral aspects of the calcaneus, Achilles tendon, as well as on the sole of the foot. The raising of the extensor digitorum brevis mucle demands the

sacrifice of the dorsal neurovascular pedicle of the foot, which means that the vascularity of the foot needs to be evaluated prior to the use of it.

The Peroneus brevis muscle flap was first described by Mathes and Nahai (Mathes & Nahai 1997). As a distally based flap, its use was first described in a series of patients by Eren (Eren et al 2001). This flap can well cover soft tissue defect on the lateral side of the ankle.

The use of local muscle flaps is often hindered by their small size and by the extent of rotation, however they provide us with a simpler, less expensive way to reconstruct soft tissue defects in the foot and ankle area. As a result, local muscle flaps may very well challenge the use of microsurgical free flaps in this area (Attinger et al 2002, Verhelle et al 2005).

2.6 SOFT TISSUE RECONSTRUCTIONS WITH FREE FLAPS

When the defect is larger, the repair becomes more demanding (Pu 2007). Often after the revision of the wound, there is too little local tissue for the soft tissue reconstruction (Chun et al 2000, Suominen et al 1992). Furthermore the donor area for the local flap can also be damaged due to the prior trauma.

Now with more than 30 years of free flap surgery, many different flaps have been used in the ankle and lower leg area for soft tissue reconstruction (Daniel and Taylor 1973, Rautio 1990, Khouri 1992, Gonzales et al 2002). The free flaps can be divided into four types: fasciocutaneus, muscle flaps, myocutaneus and perforator flaps. The first free flap used in the lower-leg reconstruction was the groin flap in 1973 (O´Brien et al 1973). Since then, other less bulky flaps have been used more frequently such as the like radial forearm (RF) and the lateral arm flap (Chan et al 1982, Chun et al 2000, Waris et al 1991, Weinzweig and Davies 1998). These are relatively thin which is a benefit in in the ankle reconstructions (Duffy et al 2005). Both of these less bulky flaps also have a long pedicle and this makes the choice of the anastomosis site easier (Hallock and Arangio 2007). However, using the RF involves the patient having to sacrifice a major artery of the hand and often a need for a free skin graft for the coverage of the donor site. One less frequently used flap in the lower leg reconstruction is raised from the instep area from the other foot, which leaves a skin grafted area on the otherwise healthy foot and is quite difficult to raise (Morrison et al 1983).

In case of infection, it has been observed that free muscle flaps bring well-vascularised tissue to the infected area (Lentz et al 1979, Nieminen and al 1995). The muscle flaps covered with a split-thickness skin graft can be used to cover large defects and cavities (Lin and Wei 2000). The most commonly used of these muscle flaps are the latissimus dorsi (LD), the gracilis and the rectus abdominis muscle. The LD as a free flap can be raised as a flap that is myofascial, myocutaneus or

even as a composite osteomyocutaneus flap. However the gracilis muscle is mostly used as a myofascial flap. When the patient is lying supine, the rectus abdominis free flap is easy to raise.

Musculocutaneus flaps have also been used in the foot, but they are often too thick, nor do they have the durability needed for heel-area reconstructions (Rautio 1990).

However, the use of perforator flaps has increased in the last years and especially the anterolateral thigh flap (ALT) has proven successful in different reconstructions (Chen et al 2005, Felici and Felici 2006, Yildirim et al 2006). The ALT is often bulky, especially in the obese patients, but it can be thinned (Ozkan et al 2004).

Thus the selection of the best free flap for the ankle area is still not settled (Yazar et al 2006). Many factors influence the selection process such as the age and general health of the patient, possible obesity, vascular disease, diabetes, and cigarette smoking. In addition, the surgeons experience and the position of the patient (especially when dealing with multiple trauma areas) are factors that are important. In most cases, it seems that a surgeon uses the few flaps he/she best masters. The common flaps used for soft tissue reconstruction in the ankle area are listed in table below (Attinger 2002, Mathes&Nahai 1997, Nieminen et al 1995).

Ideally the soft tissue reconstruction should be performed with a method selected according to the localisation, size and shape of the defect.

Table 1 Common flaps used in the ankle area

Pedicled flaps	Microvascular flaps
	Fasciocutaneus flaps
Peroneus brevis flap	Radial forearm
Peroneus longus flap	Lateral arm flap
Flexor digitorum longus flap	
Flexor digitorum brevis flap	Scapular flap
Flexor hallucis longus flap	Groin flap
Extensor digitorum longus flap	
Extensor digitorum brevis flap	ALT
	Thoracodorsal artery perforator flap
	Muscle flaps
	Gracilis muscle
Extensor hallucis longus flap	Latissimus dorsi
Abductor hallucis flap	Rectus abdominis muscle flap
Abductor digiti minimi flap	Fascia flaps
Posterior tibial artery flap	Tensor fascia lata free flap
Peroneal artery flap	Temporalis fascia free flap
Anterior tibial artery flap	Serratus fascia flap
Tibialis anterior flap	
Tibialis posterior flap	
Suralis flap	
Random skin flaps	
Bipediculed flap	

2.7 NEGATIVE PRESSURE WOUND THERAPY

Negative pressure wound therapy (NPWT) has gained popularity during the last decade because it can make the reconstructive operation easier (Schlatterer and Hirshorn 2008). With NPWT the wound is covered with foam which has embedded tubing. The site is subsequently covered with an adhesive plastic sheet and the tubing is connected to a vacuum assisted pump. At this point continuous or intermittent negative pressure suction is applied. Furthermore the dressings are usually changed every other day. This decreases the oedema in the tissues and thereby decreases the size of the wound. The vacuum also increases the amount of granulation on the wound bed, making it possible to cover the wound with a free skin graft (DeFranzo et al 2001), thereby sparing the patient from microsurgery. The NPWT is also said to control the oedema and promote tissue revascularization (Pollak 2008). The main criticism reported for this has mainly been that it does not reconstruct the defect in question, but only helps the final coverage procedure (Levin 2008). The NPWT has generally become most often the first treatment for soft tissue defects in the lower leg (Schlatterer and Hirshorn 2008). However the NPWT was not yet in use during this study in Töölö Hospital.

3. AIMS OF THE PRESENT STUDY

The purpose of the present study was to examine retrospectively the postoperative soft tissue defects, the possible risk factors for them and the different reconstructive methods. The specific aims of the study were:

1. To study the results of reconstructions of soft tissue defects after Achilles tendon surgery and as for the different methods used to reconstruct soft tissues in the different size defects, how have these worked?

2. To investigate, based on previously operated patients, the possible risk factors for postoperative soft tissue problems after calcaneal fracture surgery.

3. To evaluate the use of the local flaps and microvascular flaps in the soft tissue reconstruction after calcaneal surgery in a clinical series.

4. To study the risk factors for the postoperative complications after Talocrural Arthroplasties and to investigate the results after the microvascular soft tissue reconstruction.

5. To investigate if the distally based peroneus brevis muscle flap is suitable for soft tissue reconstruction after a trauma to the lateral aspect of the ankle.

4. PATIENTS AND METHODS

This retrospective study focuses on the postoperative soft tissue defects in the Ankle area. The specific areas in question are the Achilles tendon (study I), Calcaneal bone (studies II and III), Ankle joint (study IV) and Lateral Ankle area (study V). A total of 196 patients were enrolled in this study. The time of their operative treatment was between 1993–2003.

4.1 ETIOLOGICAL FACTORS FOR SOFT TISSUE DEFECTS AFTER ACHILLES TENDON SURGERY

Twenty-five patients treated between 1996–1999 at the Helsinki University Central Hospital Department of Plastic Surgery were interviewed 6–56 months after the soft tissue reconstruction of the Achilles tendon area. The average age for the patients was 52.3 years at the time of the surgery. The underlying procedure was an operatively treated Achilles tendon rupture for 12 patients and a tenolysis operation for 13 patients. The possible predisposing factors for the postoperative soft tissue problems were: cortisone injections to the tendon (six patients), cigarette smoking (3), diabetes mellitus (2) and rheumatoid arthritis (1).

The patient data and methods of reconstructions are listed in the table below.

Table 2. Soft tissue defects and methods of reconstructions after complicated Achilles tendon surgery operations

Age/Years	Sex M/F	Size height x width cm	Primary operation	Reconstruction method
54	M	2 x 0.5	Tenolysis	resuturing
88	M	3 x 3.5	Rupture repair	Revision+free skin graft
69	F	2 x 3	Rupture repair	Revision+free skin graft
57	M	2 x 3.5	Rupture repair	Revision+free skin graft
69	M	6 x 4	Rupture repair	Revision+free skin graft
39	M	3 x 1.5	Rupture repair	Transpositional flap
36	M	4 x 2.3	Tenolysis	Transpositional flap
53	M	3.5 x 2.5	Tenolysis	Transpositional flap
58	M	3.5 x 2	Tenolysis	Bipedicle skin flap
47	M	5 x 3.5	Rupture repair	Bipedicle skin flap
20	M	4 x 2	Tenolysis	Bipedicle skin flap
55	M	4 x 2.5	Rupture repair	Bipedicle skin flap
63	F	4 x 2	Tenolysis	Bipedicle skin flap
68	F	3.5 x 2.5	Tenolysis	Bipedicle skin flap
35	F	3 x 2	Tenolysis	Bipedicle skin flap
54	F	5 x 2	Rupture repair	Bipedicle skin flap
77	M	3.5 x 1.5	Tenolysis	Bipedicle skin flap
42	M	4 x 1.5	Tenolysis	Bipedicle skin flap
60	M	4 x3	Rupture repair	RF
41	M	3 x 4.5	Tenolysis	RF+Palmaris longus tendon
40	M	5 x 4	Rupture repair	RF
61	M	6 x 3	Tenolysis	RF
44	M	4.5 x 3.5	Rupture repair	RF
38	M	3 x 5	Tenolysis	RF
40	M	5.5 x 3	Rupture repair	RF

4.2 METHODS OF SOFT TISSUE RECONSTRUCTION IN THE ACHILLES TENDON AREA

In most cases, the debridement and excision were performed in the same operation as the reconstruction. The reconstructive method was chosen according to the defect size, shape and location, as well as the patient's physical health (Table 2). When the defect was less than 5 mm in width, it was repaired by simple resuturing the wound (1 case). In the wider, but still long defects, a bipedicular flap was used (10 cases). In round defects transpositional flaps were used (3 cases). If the tendon had to be resected, the defect was covered with a free flap in seven patie-

nts (sometimes together with tendon reconstruction) and a free skin graft in the older patients (3 cases).

4.3 ETIOLOGICAL FACTORS FOR SOFT TISSUE DEFECTS IN THE CALCANEAL BONE AREA

Calcaneus fractures were mainly caused by a fall (84%) from one to 17.5 meters. Other injury mechanisms were: a traffic accident (10%) and miscellaneous (6%). Out of the 126 patients studied, 22 had bilateral fractures and 55 patients had additional fractures. A typical patient was a middle-aged man. Out of the patients, 3% had diabetes and 40% were smokers.

In most cases, the fracture affected either the subtalar joint or the subtalar and the calcaneocuboidal joint. The fracture fixation was made with an AO-plate and screws in most cases (135) and with screws only (8), Kirschner wire (4) or with Kirschner wire with absorbable rods (1).

The number of surgeons performing the operations was high (33) and this was because Helsinki University Central Hospital is the major teaching hospital for trauma surgeons in Finland.

4.4 SOFT TISSUE RECONSTRUCTIONS IN THE CALCANEAL BONE AREA

The material was restricted to patients without additional fractures. The fracture classification was made according to Sanders (Sanders 1992) and can be seen in the table below.

Table 3. Classification of the Calcaneal fractures

Type of fracture	Number of fractures
I	1
IIa	5
IIb	3
IIIab	3
IIIac	4
IV	13
Miscellaneous	11
Total	40

The miscellaneous fractures did not affect the talocalcaneal joint and therefore the Sanders method could not be used to classify them. Out of these 11, six affected

only the tuber calcanei, two calcaneocuboidal joints and three were shears of the calcaneal bone.

The osteosynthesis was performed on the average 5.9 days after the injury (range 0–15 days). In 18 cases, this was done by using a metal plate and screws and in 12 cases, with Kirschner wires, and in 4 cases by using screws alone.

The soft tissue defect was either caused by the primary injury or by a postoperative complication. On average, one debridement was performed prior to the reconstructive procedure, which was performed usually within two months after the primary fracture (mean=54 days, range from 10 days – 10 months).

The methods of reconstruction can be seen below.

Table 4. Reconstruction methods used after complicated Calcaneal fractures

Free flaps	
Gracilis muscle free flap	11
Anterolateral thigh	5
Rectus abdominis	3
Latissimus dorsi	2
Local flaps	
Suralis flap	8
Muscle flap	3
Skin flap	3

The free flaps were anastomised to the posterior tibial artery (16), the tibial artery (3) and to the dorsalis pedis artery (2). The following muscle flaps used were: an adductor hallucis on a medial defect, a flexor digitorum brevis on a plantar defect and a distally based PB flap on a lateral defect.

4.5 SOFT TISSUE RECONSTRUCTIONS AFTER ANKLE ARTHROPLASTY OPERATIONS

Out of the seven Talocrural Arthroplasty patients, four had post-traumatic arthritis, two had rheumatoid arthritis and one secondary arthritis due to infection. Six of the patients smoked cigarettes, four had diabetes mellitus, two took cortisone medication orally and two had arteriosclerosis. At the time of their referral to our clinic (2–4 weeks from the arthroplasty), all had skin necrosis and wound dehiscence.

The lower extremity blood flow of these patients was investigated at the vascular laboratory. This included the ankle brachial pressure index (ABI) and Doppler and one patient had an angioplasty.

A connection from the skin defect to the TCA components was evident in six cases. First, the dead and infected tissue was removed, the meniscus of the prosthesis was also temporally removed and the area was then cleaned with jet lavage. At this point, the decision was made to remove or to retain the prosthesis.

The methods for the patients soft tissue reconstruction are listed below.

Table 5. Sizes of the defects and methods of soft tissue reconstruction after TCA

Patient No.	Size of the defect, height x width	Method of reconstruction
1	5cm x 3cm	LD free flap
2	10cm x 3cm	LD free flap
3	7cm x 3cm	LD free flap
4	1cm x 1cm	LD free flap
5	10cm x 5cm	RF free flap
6	7cm x 4cm	Musculus Gracilis free flap
7	1cm x 5cm	Musculus Gracilis free flap

4.6 THE DISTALLY BASED PERONEUS BREVIS FLAP IN THE LATERAL ANKLE AREA

Lateral defects around the ankle were covered with the distally based PB flap. Thirteen patients had defects in the lateral aspect of the ankle, two on the lateral side of the calcaneus bone and one had a defect in the Achilles tendon area. All those were postoperative defects. Their aetiology varied as followed: trimalleolar fracture (6 patients), bimalleolar fracture (2), lateral malleolar fracture (1), calcaneal bone fracture (2), tibial fracture (3), Achilles tendon rupture (1) and a post-traumatic soft tissue defect (1). Out of the 16 patients, two were smokers, two had diabetes mellitus and one was on cortisone medication.

All of the soft tissue reconstructions were performed by using the distally based PB flap covered with a split-thickness skin graft. The operating time was on the average 81 minutes and the operations were performed by four different plastic surgeons.

4.7 STATISTICAL METHODS

Due to the small number of patients in most of the studied groups, the statistical information could only be used in Study II, and the Mann-Whitney and the T-test were used. That analysis was made by Mr Timo Pessi.

5. RESULTS

5.1 SOFT TISSUE RECONSTRUCTIONS AFTER ACHILLES TENDON SURGERY

All the patients wounds had healed by the time of the interview (average 30 months, range 6–56 months), the functional result was also acceptable in all cases.

When the repair was revision and re-suturing, the healing was unproblematic and the patient had no complaints about the ankle function postoperatively.

Out of the local flaps used, the bipedicled flap healed well in eight out of the ten cases. In the transpositional flaps, the ratio was one out of three. This is due to the vascularity of the flaps, the transpositional flaps being rotational flaps. All in all, out of the 13 patients treated with local flaps, 12 complained of restricted movement in the talocrural joint.

With the elderly patients (average age 70.8 years) treated with a total removal of the Achilles tendon and free split thickness skin graft, three out of four healed well. For one patient, the primary revision created a large soft tissue defect that needed to be filled with a Musculus Gracilis free flap.

The free flaps used were mostly RF (7/12). The main complaints postoperatively for these flaps concerned the bulkiness of the reconstructed area or the aesthetic result of the donor site. Only one patient complained of restricted movement.

5.2 WOUND COMPLICATIONS AFTER OPERATIVELY TREATED CALCANEAL BONE FRACTURES

The number of post-operative complications after surgery was 24%. These were divided into wound edge necrosis (8%) and wound infection (16%). A total of 14 % needed operative treatment, the rest were treated conservatively.

The predisposing factors affecting postoperative wound complication were a delay from injury to surgery and operation time. In this study the average delay between injury to surgery was 7.8 days ($p=0.02$) and the longer the delay, the more probable the complications became. There was also a correlation between the wound complication group with a higher number of additional spine fractures compared to the non-complicated ones (24% versus 14%). Together these two facts can indicate that for patients with spine fractures the treatments were first focused on

them and thus after a longer delay to the complex calcaneal fractures. The average operation time was 101 minutes (p=0.04). No correlation was found between the wound complications and age, sex, height of fall, fracture classification and smoking.

5.3 SOFT TISSUE RECONSTRUCTIONS IN THE CALCANEAL BONE AREA

The recovery was uncomplicated in 28/35 cases. Those with complications included three flaps needed revisions due to skin edge necrosis and one Suralis flap failed that totally and was replaced with a LD free flap. In addition a deep infection was encountered in two cases, one of them was treated conservatively and the other was covered with a Musculus Gracilis free flap. Due to bulkiness, two flaps were later thinned (one LD and one ALT).

At follow-up (average 14 months, range 3–48 months) all soft tissues had healed and bony union was recorded. At this point, no signs of calcaneal osteisitis were found at that point.

5.4 SOFT TISSUE RECONSTRUCTIONS AFTER ANKLE ARTHROPLASTY OPERATIONS

The prosthesis was salvaged in four out of the seven patients and no amputations were needed. Nonetheless, all had restricted movement in the talocrural (TC) joint afterwards, possibly due the demanding immobilization after reconstructive procedure. Three arthrodesis were needed, which resulted in a 2–4 cm shortening of the affected limb. All free flaps healed well, with only one LD flap needing distal end revision.

5.5 SOFT TISSUE RECONSTRUCTIONS USING THE DISTALLY BASED PERONEUS BREVIS MUSCLE FLAP AFTER LATERAL ANKLE AREA TRAUMA SURGERY

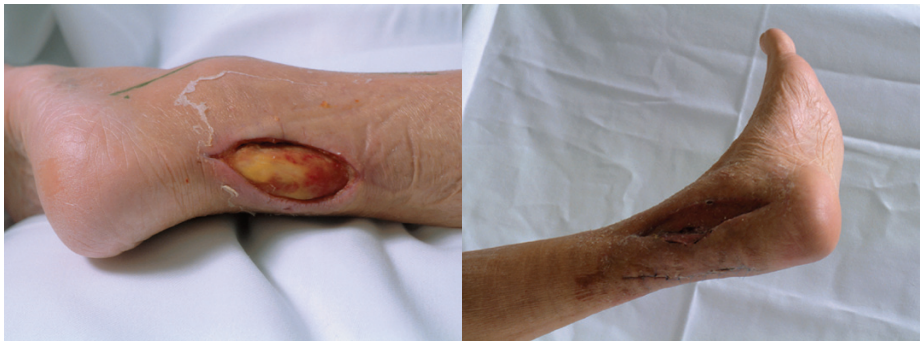
Out of the sixteen flaps, eight healed perfectly (50%). The problems, that could be dealt with consertive treatment were encountered in three of these flaps (2 cases of fistulation and one small distal necrosis of the flap). Three needed debridement due to distal necrosis of the flap and coverage with a free thickness skin graft. In one, a debridement was needed because of the fistulation. In one case, the flap failed to cover the hardware and was replaced with a LD free flap.

In 15 of the 16 patients, the distally based peroneus brevis muscle was successful in covering the lateral defect in the ankle. Furthermore, no delay in the bony union of the fractures among the cases could be seen. The results are summarised in the table below.

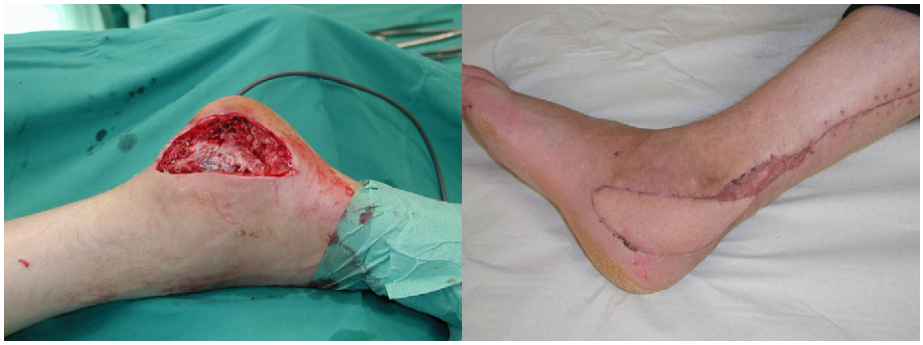
Table 6. 16 Consecutive patients with distally based PB flaps used for soft tissue reconstruction in the lateral ankle region

Patient No.	Age/Sex	Defect site	Defect size, height x width (cm)	Complications	Follow-up time (months)
1	51/female	lateral malleolus	2 x 1	distal necrosis, free skin graft	1.5
2	55/male	lateral calcaneus	2 x 1	none	2
3	68/female	lateral malleolus	9 x 3	none	3
4	47/female	lateral malleolus	10 x 3	none	4
5	47/female	lateral malleolus	7 x 3	fistulation, revision	3
6	69/male	lateral malleolus	15 x 2	delayed wound healing	5
7	42/male	lateral malleolus	11 x 3.5	none	7
8	61/female	lateral malleolus	2.5 x 1.5	distal necrosis, LD-flap	12
9	52/male	lateral calcaneus	15 x 4	distal necrosis, free skin graft	12
19	56/male	lateral malleolus	7 x 2	none	22
11	45/male	achilles tendon	1 x 1	none	5.5
12	32/male	lateral malleolus	10 x 4	delayed wound healing	13
13	60/male	lateral malleolus	12 x 3	none	5
14	83/female	lateral malleolus	5 x 5	Delayed wound healing	9
15	56/female	lateral malleolus	8 x 3.5	none	12
16	50/female	lateral malleolus	12 x 4	distal necrosis, free skin graft	5

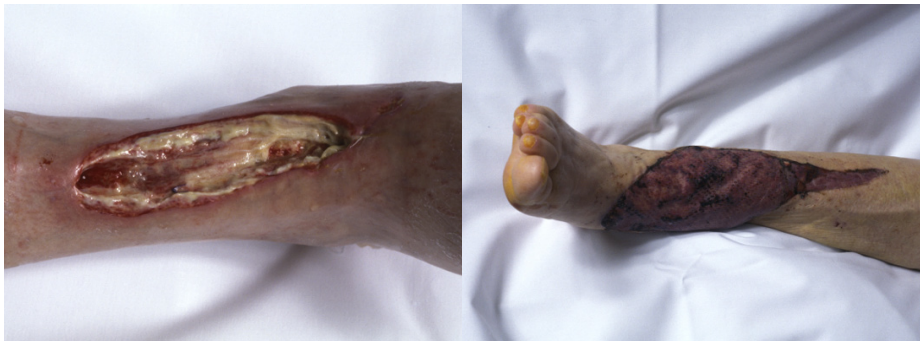
6. PICTURES OF THE RECONSTRUCTIONS



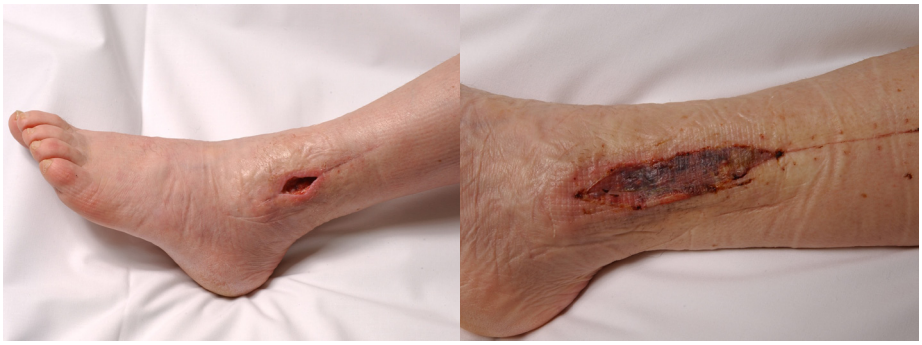
Soft tissue defect 16 days after Achilles tendon surgery and the reconstruction with a bipedicular flap after six weeks on a 47-year-old man.



An operatively treated Calcaneus fracture after debridement of the wound and the soft tissue reconstruction with a Suralis flap in a 45 year-old man.



A 65-year-old woman with rheumatoid arthritis six weeks after the arthroplasty. The same patient two weeks after the soft tissue reconstruction with a latissimus dorsi free flap covered with a split thickness skin graft.



The ankle of a 51-year-old female three months after operative treatment for a trimalleolar fracture and three weeks after removal of hardware. The same ankle following soft tissue reconstruction with a distally based PB flap with a free skin graft.

7. DISCUSSION

7.1 GENERAL OBSERVATIONS

While there are many different reasons for ankle surgery, the main reasons are due to trauma, strain and degenerative problems. To alleviate these, the surgery can be performed either as an elective procedure or because of a prior trauma. During trauma surgery, the zone of injury can damage the tissues widely and the oedema caused by the trauma complicates the tissue handling. Another fact that influences patient recovery is the small amount of loose skin and soft tissue in the area. To minimize the number of post operative wound edge necrosis and infection, the need for the right timing of surgery as well as the indications for surgery all need to be optimal. Wound complications after ankle surgery are quite common, with the numbers as high as 21-25% have been reported (Fink and Mizel 2002, Folk et al 1999). They often lead to numerous operations, longer hospitalisation and longer sick leaves, not to mention the possible permanent disorders in the functional results. Even today in papers published quite recently, reports have indicated that after surgery, some have ended up with below the knee amputations (Lawrence and Grau 2003, Sprit et al 2004).

The Helsinki University Hospital, Department of Plastic Surgery is the largest centre in Finland for soft tissue reconstructions of the ankle area. This clinical study offers additional information on the management of these soft tissue defects and on the risk factors for postoperative wound complications.

After these studies were carried out, new methods for soft tissue reconstructions such as NPWT and local propeller flaps have been adopted in everyday use.

7.2 POSTOPERATIVE WOUND COMPLICATIONS AND METHODS FOR SOFT TISSUE RECONSTRUCTION IN THE ACHILLES TENDON AREA

Many studies have compared the operative and the non-operative treatment of Achilles tendon ruptures (Cetti et al 1993, Leung et al 1993). The operative treatment is recommended in young and physically active patients due to the lower risk of re-ruptures (Järvinen et al 2001, Wong et al 2002).

Moreover, the number of postoperative wound complications has been reduced when the operations have been performed percutaneously (Khan et al 2005), however there is a higher risk for a re-rupture (Maffulli 1999). In the present study, the operations were all performed in an open manner.

The key point in preventing postoperative wound complications is the meticulous handling of tissue during surgery and the right selection of patients (Feibel and Bernacki 2003, Paavola et al 2000). In some cases, conservative treatment is a better choice and good results have also been achieved with this form of treatment (Morelli and James 2004, Movin et al 2005). Certain predisposing factors also need to be taken in consideration before surgery such as diabetes, being overweight, old age, smoking, and the vascular status of the patient (Paavola et al 2000). Taking all these into consideration in light of the results indicates that the general health of the patients needs to be evaluated better prior to operations.

Based on our study, the vertical skin defects of moderate size were reconstructed using a bipediculed skin flap, which is a useful, one-step procedure. This finding correlates the results previously been presented by Schwabegger (Schwabegger et al 1996). In short, the wound heals fast, allowing the patient to return to work quickly. For the small and round defects, we recommend them to be reconstructed with a local transpositional flap. Nonetheless, the size of the defect and the arc of rotation limit the use of it in the Achilles region. Another point is that the donor site very often needs free skin coverage and an additional scar.

In cases were the large defect hinders the use of local flaps, we recommend the use of microvascular flaps. Out of the most commonly used flaps we recommend the RF, which can be accompanied with the Palmaris longus tendon to be used for simultaneous tendon grafting. The missing tendon can be also reconstructed simultaneously with the ski defect by a fasciocutaneus ALT flap with vascularised fascia lata (Kuo et al 2003). Another option is to perform the tendon reconstruction using a fascia lata strip under the free flap (Haas et al 2003).

The morbidity of the donor site with RF presents a problem. To overcome this, many different types of fasciocutaneous free flap have been used to cover the exposed Achilles tendon (Brent et al 1985, Waris et al 1991). The best results in those cases that need tendon coverage are obtained with flaps that allow normal tendon movement.

The operated area is primarily numb, but sensitivity in the operated area has been reported to improve with time (Rautio 1990).

Muscle free flaps such as the gracilis and latissimus dorsi have commonly been used in large defects and to cover the exposed fractures in the lower extremity to enhance healing and to fill in large cavities (Gonzales et al 2002). According to our study, the RF works well as a reconstructive method on an exposed Achilles tendon, since there seldom is a large cavity needing to be filled or bone to be covered.

7.3 ETIOLOGY FOR POSTOPERATIVE SOFT TISSUE COMPLICATIONS AFTER CALCANEUS FRACTURE SURGERY AND THE POSSIBLE METHODS FOR SOFT TISSUE RECONSTRUCTIONS

Although the operative treatment of calcaneus fractures seems to improve the outcome, too few studies have been conducted for a strong recommendation for this (Randle et al 2000). Open reduction and internal fixation of dislocated calcaneal fractures has become popular because this gives better functional results than for the conservative treatment or the percutaneous pinning (Therman et al 1998).

Nevertheless, the wound complication rate after internal fixation remains high. The rate in our study was 24%, which is equivalent to the numbers presented in previous studies ((2.7%)Bèzes et al 1993, (9.7%)Chan and Ip 1995, (25%)Folk et al 1999).

The classification of fractures correlates positively to the postoperative wound healing problems, namely the more complicated fractures have more postoperative complications (Lawrence and Singhal 2007). Furthermore, the more comminuted fractures tend to have more wound healing problems. The more complex fractures also increase the operating time, which has been found to correlate to the postoperative wound problems (Malik et al 2004). This is due to disruption of the microcirculation in the area and in the soft tissue envelope of the calcaneus (Therman et al 1998).

In our study, we found a positive association between a long delay in surgery and wound complications ($p=0.02$). In addition, the long operating time seemed to have a positive correlation with the postoperative wound problems ($p=0.04$). The incidence of complications seemed to rise after two days, thereby indicating that these fractures should be operated on as soon as possible.

Previously it has been stated that the operation should be delayed until the skin wrinkles, which usually by elevating the leg, takes at least one week (Bèzes et al 1993). The average time from trauma to surgery in this study was 7.8 days (range 0–24 days). The delay between trauma and surgery can also be caused by the difficulty of the trauma or by additional fractures.

In our material the number of surgeons was much higher than in other studies, this however had no statistical correlation with the wound complications. The reason for the high number of surgeons might have been that the more complicated fractures were left to the senior surgeons.

In conclusion, to avoid wound complications, the following is advised: select the patients more carefully (specially those with a high energy trauma) and operate as soon as possible. It is our recommendation that an experienced surgeon

should operate complex fractures thereby minimising both the tissue trauma and operating time could be reduced.

The injuries of the calcaneal bone produces swelling of the soft tissues and put substantial tension on the wound that was created during osteosynthesis. The possibility of wound infection or skin edge necrosis is well recognised, but cannot be completely avoided even if the timing and surgical technique of the operations were adequate. If infection or necrosis of the wound is registered, an early revision of the wound is suggested (Levin and Nunley1993).

Sometimes the plates and screws can be saved and covered by a flap. If the infection is fulminant, the plates and screws should be removed to control the bony infection. The bones can be fixed with Kirschner wires before removing the plate and screws to maintain the position of the fractured parts of the calcaneus. If the wound is kept clean, the defect can be covered in the same session. In a doubtful situation, the reconstruction should be delayed for a few days.

In our study (III) the LD-muscle flap and ALT fasciocutaneous flap were too bulky in 4 cases. For this reason, these flaps should not be routinely used in the heel region. Gracilis muscle was most commonly used, and seems to give satisfactory contour to the heel. The well-vascularised free flaps are reliable and the wound seems to heal faster after the free flap surgery compared to reconstructions done with local or pediculed flaps.

The suralis neurocutaneous flap has become quite popular after Masqualet introduced it in 1992 (Masqualet et al 1992). The suralis flap is quite easy to raise and the patients do not usually complain about the neural defect created by the operation. In our experience, the suralis flap fits well in the calcaneal defects because its arc of rotation reaches the heel easily and the thickness of the flap is often appropriate in relation to the defect. When calcaneal defects are reconstructed, the donor site can often be closed. Sometimes problems with venous congestion are encountered with the flap (Tu et al 1999) and as a consequence this flap is not very suitable for the reconstruction involving deep cavities or osteitis. In our series, all except one patient healed after a suralis reconstruction. In that respect the suralis flap can be recommended for the soft tissue reconstruction around the calcaneus.

Our series did not have chronic infections in the calcaneal bone, but the follow-up time in several patients was limited. Our impression is, however, that calcaneus is quite resistant to chronic infection after complications arising from open fractures or ostheosynthesis. This is probably dependent on the cancellous nature of the bone and on the well vascularised structure as compared to the long bones.

The closure of the wound is equally important; no tension should be applied to the wound during the closure. In addition, when the swelling causes too much tension, the wound should be left open until it can be closed without a problem or a flap reconstruction should be used. Moreover, the leg should be elevated post operatively.

7.4 POSTOPERATIVE SOFT TISSUE RECONSTRUCTIONS AFTER TALOCRURAL ARTHROPLASTY

The selection of the patients and the preoperative assessment of patients for TCA is crucial (Conti and Wong 2001). Apparently, total failure and removal of the prosthesis after a TCA leads eventually to worse results than a TC-arthrodesis performed primarily without attempting the arthroplasty.

Based on our studies, we recommend that all patients should all be investigated for vascular problems prior to the operations. Towards this end, the preoperative Doppler and ABI-index measurements are recommended. Yet in our material, these were not performed routinely and one angioplasty and one femorodistal bypass were needed prior to the reconstructive procedures.

If a wound problem and infection is evident, a radical debridement and a reconstruction with sufficient tension-free tissue are needed. For post operative soft tissue reconstruction in the ankle area, local tissue is often unsuitable owing to previous injury (Heitman and Levin 2003). For this reason, a microvascular free flap is often needed. In cases where the joint is open, a free flap provides good coverage and brings good, well-vascularised tissue to the area (Hallock 2000). In this material, the partial LD flap was used the most because of a longer and bigger pedicle.

After this study, the use of propeller flaps has brought an alternative to the use of microvascular flaps in reconstructing the lower leg soft tissue. One reason is because the propeller flaps limit the donor site morbidity to the same limb and bring similar soft tissue to the traumatized area (Jakubietz et al 2007). In addition, the operation does not require special resources such as a microscope and can be performed even in smaller centres.

If the soft tissues are already affected by scars, the soft tissue reconstruction should be performed simultaneously at the arthroplasty operation with the TCA as presented earlier by Heitman (Heitman and Levin 2003).

7.5 POST OPERATIVE LATERAL ANKLE SOFT TISSUE RECONSTRUCTIONS WITH THE PERONEUS BREVIS MUSCLE FLAP

The distally based PB muscle flap offers a quick and simple method of reconstructing the soft tissue in the lateral distal lower leg and the results in our series were successful. Today other studies have confirmed our results (Bach et al 2007, Fansa et al 2006). In addition to the scar, there were no problems were encountered with the donor site. The disadvantage of the flap is the size of the muscle, which makes it suitable only for small or moderate sized defects. The vitality of the distal

segment of the flap is difficult to estimate and it often needs revision. It is important that this revision be completed during the operation and the possibly poorly vascularised tip of the flap should be revised.

Revisions and episodes of delayed wound healing were encountered in our patients, indicating the low vascularity of this flap. However, in 15 of the16 cases, the final result was good after the reconstruction. At the beginning the muscle is quite dark and swollen, but it shrinks over time and the result is fairly good aesthetically.

Our results are similar to those published by Eren (Eren et al 2001). We intend to use the distally based PB flap in the future, particularly for the soft tissue defects with a maximum size of 10 x 3 cm (length x width) in the region of the lateral malleolus. In addition, the anatomy of this region makes the operation easy and fast.

In our opinion, the distally based PB flap is a suitable means of reconstructing small soft tissue defects on the lateral side of the ankle.

8. CONCLUSIONS

On the basis of the present study, the following conclusions can be drawn:

1. The overall results and the functional recovery was good after soft tissue reconstruction in the Achilles tendon region. The free skin grafts can be used to cover the defect if the tendon is removed. Random local flaps are problematic owing to the low vascularity of the area. On the other hand bipediculed skin flaps work well if the defect is longitudinal and narrow. However, a larger defect can successfully be reconstructed with a free flap.

2. Operatively treated calcaneal fractures that are delayed from injury to surgery and a longer operation time all seem to associate with wound complications. This can be due to the fact that the patients with multiple fractures and more severe fractures were operated on after a longer delay.

3. The overall results after the soft tissue reconstruction of complicated calcaneal fracture operations were good. None of the patients in our series showed signs of calcaneal osteitis during the follow-up time. Due to a similar thickness in that area, a neurocutaneous suralis flap is suitable for reconstruction. Moreover, the relatively low vascularity of the suralis flap easily leads to a delayed healing of the wound. By comparison, free flaps are effective in treating larger defects but often are too bulky.

4. An arteriosclerotic disease of the lower extremity seemed to be a major risk factor for the soft tissue complications after an ankle arthroplasty. The disease should therefore be detected and treated prior to the arthroplasty. In addition, more than half of the implants could be saved with revision and free flap coverage.

5. The distally based peroneus brevis muscle flap seems to be an appropriate method for postoperative soft tissue reconstruction in the lateral malleolar region. However, a second revision and skin grafting is often needed, but in the end the flap covers the defect well and is not excessively bulky.

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Kauniainen, May 2010

Antti Koski

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